

Grand Canyon National Park



Geology Lesson Plans

Table of Contents

What's Inside the Earth?	GEO-2
Plate Tectonics	GEO-5
Which Rock am I?	GEO-10
Grand Canyon Geologic Timeline ..	GEO-14
Canyon Carver	GEO-22
Make a Fossil	GEO-24
Fossilization Game	GEO-26
Color the Grand Canyon	GEO-29

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What's Inside the Earth?

Grand Canyon Focus:	Geology
School Subject:	Science, Math
Grade Level:	4 th through 6 th Grade
AZ Standards Addressed:	Science: 6SC-F1 PO1, PO2; 6SC-E3 PO1 Math: 6M-E1

Lesson Overview

The students will practice using the concept of scale by constructing a scale model of the earth.

Lesson Objectives

This lesson will help the students to develop an understanding of the structure and materials of the earth's interior.

Materials

- paper and crayons, markers, or colored pencils
- apple and knife
- construction paper (blue, orange, yellow, red, and white), scissors, and glue
- compass for drawing circles
- metric ruler
- food coloring (red and yellow) and baker's clay mix: flour, salt, and water
- plastic wrap or bags, large knife, aluminum foil, oven, and poster paint/brush

Background Information

In order to understand how the Grand Canyon came to be, it helps to have some basic knowledge of earth science including the theory of plate tectonics. To understand plate tectonics, it helps to know something about the earth's interior.

The planet earth is made up of three main parts: the crust, the mantle, and the core. The mantle and core are each divided into two parts. Although the core and mantle are about equal in thickness, the core actually forms only 15 percent of the Earth's volume, whereas the mantle occupies 84%. The crust, which is very thin and brittle, makes up the remaining one percent. Our knowledge of the layering and chemical composition of the Earth is steadily being improved by earth scientists doing laboratory experiments on rocks at high pressure and analyzing earthquake waves traveling through the Earth.

Because the crust is accessible to us, its geology has been extensively studied, and therefore much more information is known about its structure and composition than about the structure and composition of the mantle and core. By the large-scale process of plate tectonics, seven large plates and about a dozen smaller ones have moved about on the earth's surface through much of geologic time. The edges of the plates are marked by concentrations of earthquakes and volcanoes. Collisions of plates can produce mountains like the Himalayas, the tallest range in the world. The plates include the crust and part of the upper mantle, and they move over a hot, yielding upper mantle zone at very slow rates of a few centimeters per year. The crust is much thinner under the oceans than under the continents.

Between 100 and 200 kilometers below the Earth's surface, the temperature of the rock is near the melting point; molten rock erupted by some volcanoes originates in this region of the mantle. This zone

of extremely yielding rock is presumed to be the layer on which the tectonic plates ride. The lower mantle is made up of relatively simple iron and magnesium silicate minerals, which change gradually with depth to very dense forms.

Based on how earthquake waves travel through the earth, the outer core is presumed to be liquid while the inner core is considered to be solid. The core is presumed to be composed principally of iron and nickel.

Procedures

1. Have students draw a picture answering the questions below:
 - Where do you live?
 - What is your house on top of?
 - What is the dirt on top of?
 - What are the rocks on top of?
2. Have a discussion on what the students believe the earth is made of and capture ideas on the board.
3. Present an apple as representing the earth. Cut the apple in half. Discuss the make up of the apple by talking about it having skin, an inside, and a center. Discuss whether the earth would have similar characteristics. Point out that the skin could be the crust, the heart the mantle, the seed covering the outer core and the seed the inner core. On the back of their picture, have students draw the apple as a model of the earth with all parts named.
4. Using various colored construction paper, have each student cut circles modeling the layers of the earth. Use the chart below to determine circle diameters and colors for each layer. Label each circle at the top with its layer name. Glue the crust circle on white paper, gluing successive layers on top, largest to smallest.

Layer	Radius (km)	Relative Volume (%)	Suggested Color	Diameter of Paper Circles
Inner Core	0 - 1216	0.7	Red	2 cm
Outer Core	1216 - 3486	14.3	Yellow	6 cm
Mantle	3486 - 6336	84.0	Orange	10 cm
Crust	6336 - 6371	1.0	Blue	10.2 cm

5. Prepare baker's clay by mixing two cups of flour, one half cup of salt, and one half cup of water with hands (you may need to adjust these ratios depending on the size of your class and the size of the models made). Add additional water until mixture forms a ball. Knead until the salt feels dissolved (about five minutes). Clay should be very firm (not overly moist) and smooth. Cover or put in a plastic bag until ready to use.
6. Have students divide the clay into volumes which they believe correspond to the volumes that match the percentages given in the chart above. You may wish to have the students "problem solve" this part of the activity to figure out the best and most accurate method to do this. Color the layers with food coloring to match the colors in the chart above (except the crust). Since the crust is so thin, it is easier to paint the blue on the outside of the model after it is baked.

7. Roll the smallest volume (inner core) into a sphere. Cover inner core with each successive layer of colored clay, each time making a concentric hemispherical layer. Cut the 3-D clay Earth model in half. You should be able to see the interior layering. The relative volumes will be more understandable after constructing the model.
8. Bake the halves of the model on aluminum foil, flat side down, in a 200 degree F (94 degree C) oven until dried. Baking time takes one hour for every one centimeter of dough thickness. Paint the spherical exterior with poster paint to represent the crustal layer. An additional coating of acrylic or polymer will protect the painted surface (optional).

Extension

To help students understand more about the inside of the earth, read and/or discuss the book "Magic School Bus Inside Earth" by Joanne Carro.

Plate Tectonics

Grand Canyon Focus:	Geology
School Subject:	Science, Social Studies, Math
Grade Level:	4 th through 8 th Grade
AZ Standards Addressed:	Science: 1SC-F2 PO1, PO2; 2SC-E1 PO1(4-5); 6SC-E3 PO1(4-5); 6SC-E4 PO1, PO2 (4-5), PO1(6-8); 6SC-E5, PO2 (4-5), PO1(6-8) Social Studies: 3SS-F1 PO1, PO5, PO7; 3SS-E3 PO3; 3SS-D1 PO1

Lesson Overview

Students will label maps, and use them to demonstrate change over time due to plate tectonic movements.

Lesson Objectives

Students will become familiar with the theory of plate tectonics through an activity that helps them understand how continents move slowly over millions of years. This will help students on the field trip better understand the formation of Grand Canyon's rock layers and the uplift of the Colorado Plateau.

Materials

- present day map of the world
- scissors, stapler (heavy duty best), and crayons, markers or colored pencils
- copies of figures 1-20 for each student (preferably on thick paper such as card stock)
- calculator

Background Information

The belief that continents have not always been fixed in their present positions was suspected long before the 20th century. However, it was not until 1912 that the idea of moving continents - called *Continental Drift* - was first proposed by a German meteorologist named Alfred Wegener. Wegener's theory was based in part on what appeared to him to be the remarkable fit of the South American and African continents, by the occurrence of unusual geologic structures, and of plant and animal fossils found on matching coastlines. Drifting continents also helped explain the evidence of dramatic climate changes on some continents such as tropical plant fossils found in Antarctica. Wegener's proposal was not well received at the time. However, after his death, new evidence from ocean-floor exploration and other studies rekindled interest in Wegener's theory starting in the 1950s and the theory of plate tectonics was born.

One of the exciting advances in geology has been the realization that the continents and substantial parts of the bordering ocean floor have slowly moved with respect to each other and that the outermost layer of the Earth's crust is made up of lithospheric plates. As these thin plates of ocean and continental crust move, they change the positions of the continents; the theory that describes their formation, movement, and destruction is called plate tectonics. The North American plate is slowly moving at the rate of about an inch per year. About 200 million years ago, a supercontinent (called Pangea) linked North and South America, Africa, and Europe.

What drives plate tectonics? Most scientists believe the plates slowly move from the force of convection currents and from the creation of new crust. Below the rigid plates, hot, softened mantle, heated by radioactive decay and residual heat leftover from the formation of the earth, is slowly moving in a circular motion, somewhat like a pot of thick soup when heated to boiling. The heated soup rises to the surface, spreads and begins to cool, and then sinks back to the bottom of the pot where it

is reheated and rises again. This cycle is repeated over and over to generate what scientists call a convection cell or convection flow. This circular motion of the mantle carries the continents along in much the same way as a conveyor belt.

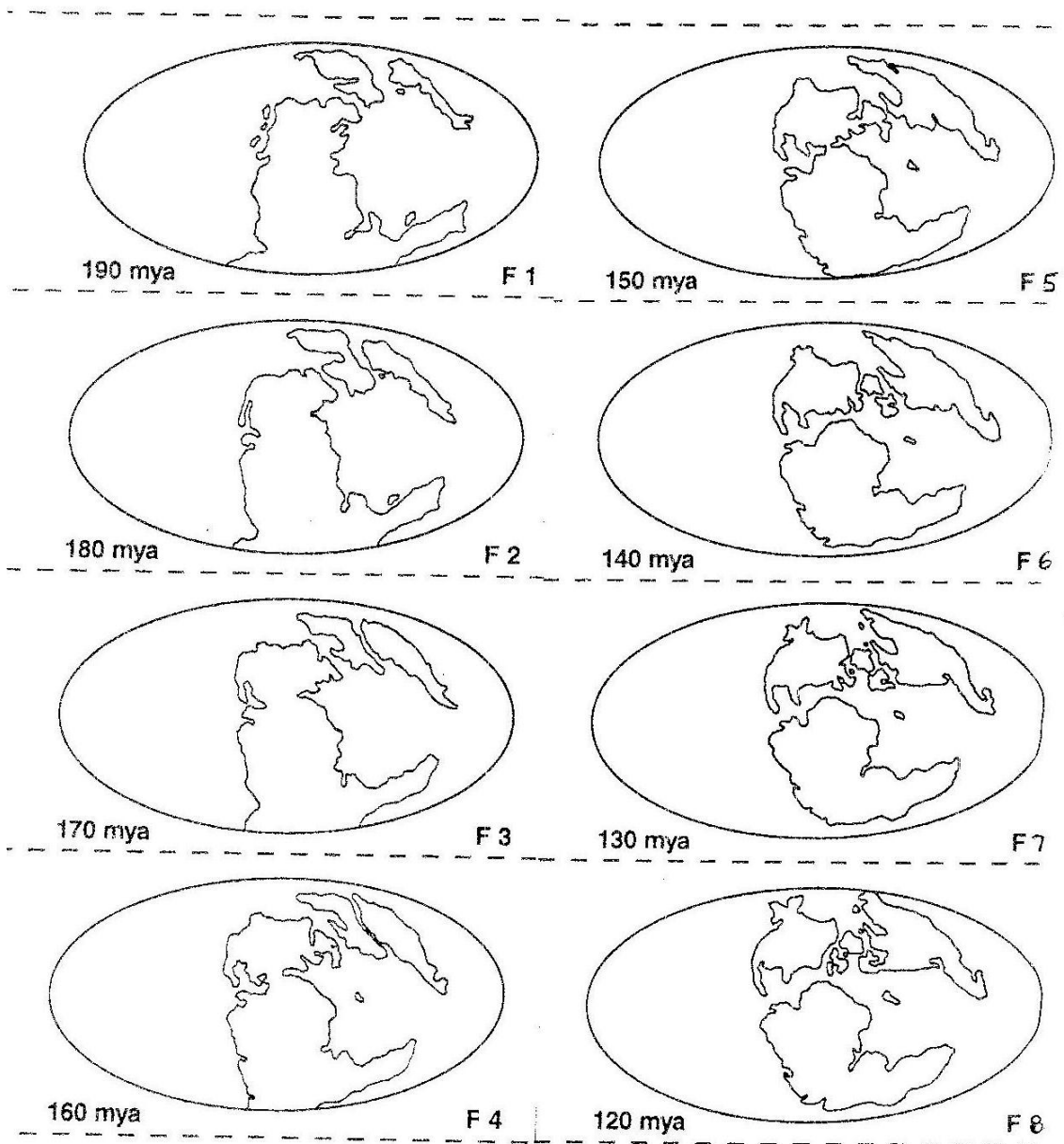
Look at an atlas, globe or map and identify the mid-ocean ridge, a series of huge mountain ranges that extend along the floors of the oceans. Along these ridges, the plates are moving away from each other. This is known as sea floor spreading. As they move apart, magma (molten rock) escapes from the mid-ocean ridge, cools and hardens, thereby adding to the crust at each side of the ridge. This theory is supported by dating the rocks on the ocean floor. Rocks right at the mid-ocean ridge are the youngest; the further the rocks are from the mid-ocean ridge, the older they are.

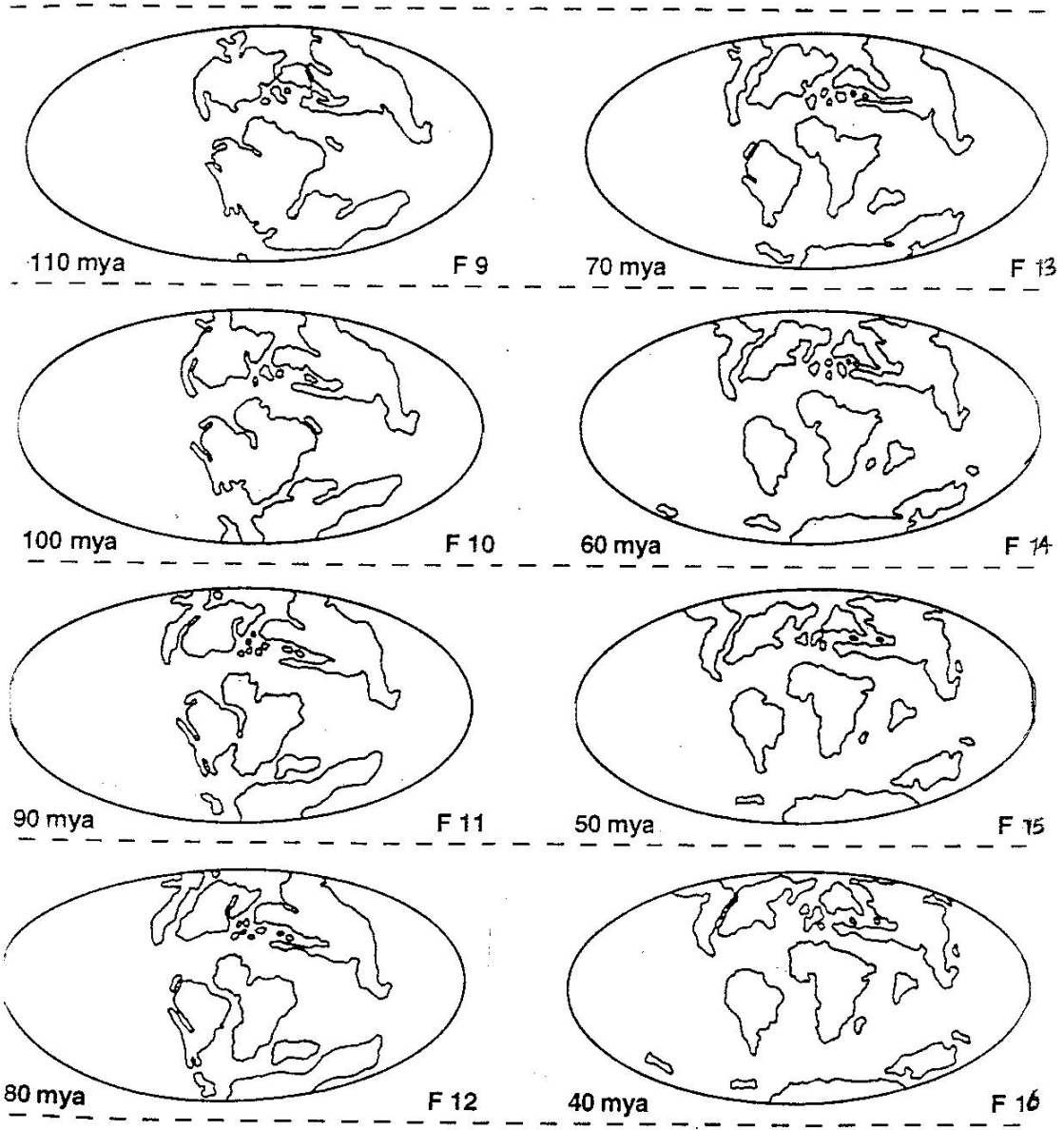
What happens to all the new sea floor that is created when magma escapes from the mid-ocean ridge? There are no rocks on the ocean floor older than 200 million years. In addition, our earth is not getting bigger, so for all the new crust that is created, some must be destroyed. This appears to happen where plates collide, and is called plate convergence. When two plates of different densities move toward one another, the denser plate slides under the other and it is forced back into the hot interior of the earth's center. Places where one plate is forced under another are called subduction zones. Earthquakes and volcanoes are common along these convergent plate boundaries. Since oceanic crust is made of denser, heavier material than is continental crust, it (the oceanic plate) dives beneath the lighter continental crust when the two collide.

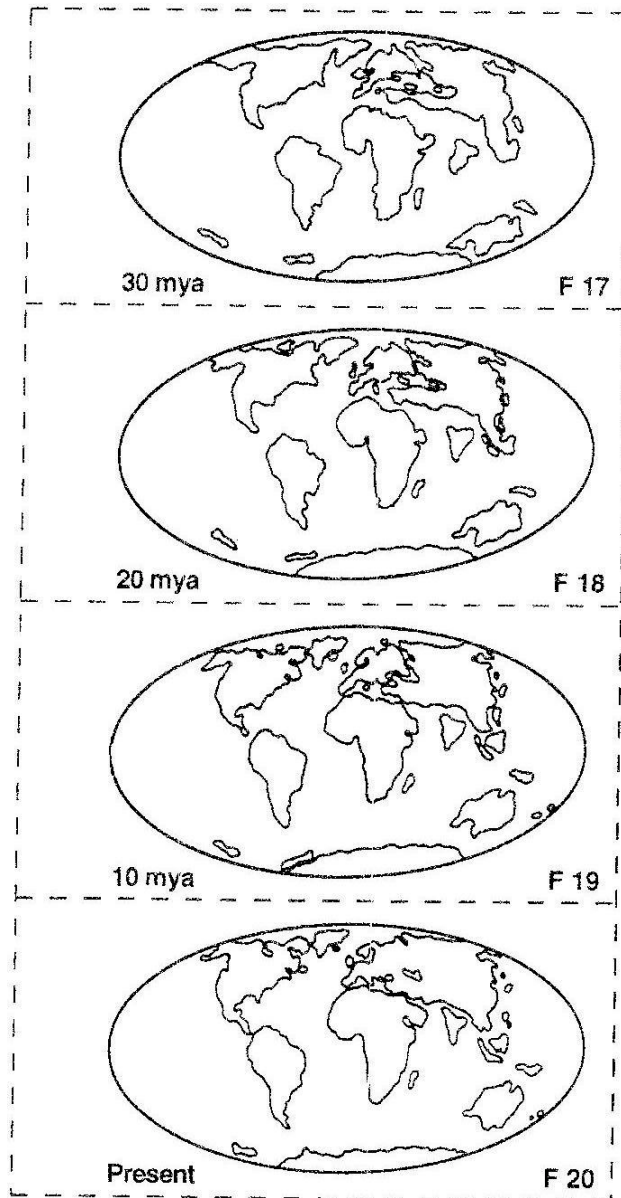
Procedure

1. Discuss plate tectonics with the students. Look at a present day map of the world and use it as a key to name each of the continents shown on Figure 20 (Present). MYA means Million Years Ago.
2. Have the students color the North American continent on each figure the same color, starting with Figure 20 and working back through time. (You can also have each student choose a different country or continent to color the same on each of their figures.)
3. Each student should then cut the rectangles apart, keeping each rectangle about the same size as the others. Cut out a cover using the extra paper on the page with the following figures. Assemble the rectangles by date with the present at the top or bottom of the stack. Align the right side of the rectangles and staple the books on the left side. Left-handed students may wish to reverse the alignment and staple area. A heavy duty stapler may be required.
4. Now each student can flip through their book to watch the continents move through time. If each student colored a different continent, students can trade books to see how other continents have moved. If the pages do not flip easily, students may need to slightly "stair-step" the pages from bottom to top. **Heavier paper may also help.**
5. North America has been moving northwestward at the rate of about an inch per year. Figure out how far it has come in the past 200 million years by using the following information; there are 5,280 feet per mile and 200 million is expressed mathematically as 200,000,000 (2×10^8).
6. Now find where you live on a map and figure out approximately where it was 200 million years ago, using latitude and longitude. Look on the map and see what exists now at that longitude and latitude. What is the climate like at that spot? How does it compare to the climate where you live now?

*Adapted from *Project Earth Science: Geology*, by National Science Teachers Association, 1996.







Which Rock Am I?

Grand Canyon Focus: Geology
School Subject: Science
Grade Level: 4th through 8th Grade
AZ Standards Addressed: 6SC-E3 PO2 (4-5)

Lesson Overview

After giving a brief explanation of the different types of rocks, students will listen to rock cycle process scenarios and go to the station that best describes the rock type.

Lesson Objectives

The student will learn about the three types of rocks (igneous, metamorphic and sedimentary), the rock cycle, the earth's dynamic nature (rocks are ever-changing), and that the Grand Canyon has all three types of rocks (sedimentary being the most abundant).

Materials

- 4 scenarios (see pages 31-32)
- 1 card for each rock type. The cards should be large enough to read from a distance and should include the following information:
 - Igneous—melt and cool
 - Metamorphic—extreme heat and pressure causes change
 - Sedimentary—erode, deposit, cement

Background Information

Rocks are continually changing. Wind and water wear them down and carry bits of rock away; the tiny particles accumulate in a lake or ocean and harden into rock again. Modern geologists recognize three groups of rocks according to the major Earth processes that formed them: igneous, sedimentary, and metamorphic. You can see all three rock types at Grand Canyon National Park.

Igneous rocks are formed from melted rock that has cooled and solidified. When rocks are buried deep within the Earth's crust, they sometimes melt because of the high temperatures. The molten rock (called magma) can then flow upward or even be erupted from a volcano onto the Earth's surface. When magma cools slowly, usually at depths of thousands of feet, crystals grow from the molten liquid, and a coarse-grained rock forms such as granite. When melted rock cools rapidly, usually at or near the Earth's surface, the crystals are extremely small, and a fine-grained rock results such as basalt.

Sedimentary rocks are formed at the surface of the Earth, either in water or on land. They are layered accumulations of sediments - fragments of rocks, minerals, or animal or plant material. If a layer of sediment is buried beneath overlying rock, the layer becomes compacted and may form a layer of sedimentary rock. The sediment becomes cemented together by minerals and chemicals or is held together by electrical attraction. Sand and gravel on beaches or in river bars look like the sandstone and conglomerate they may become. Compacted and dried mud flats harden into shale. Mud and shells settling on sea floors can cement into limestone.

Sometimes sedimentary and igneous rocks are subjected to pressures so intense and/or heat so high that they are completely changed. The process of metamorphism does not melt the rocks, but instead transforms them by reorganizing and changing their crystalline structure. New minerals are created

either by rearrangement of mineral components or by reactions with fluids that enter the rocks. Pressure or temperature can even change previously metamorphosed rocks into new types of metamorphic rock.

Procedures

1. Set up the three rock type cards where students can see them as stations in different areas of the room.
2. Explain there are many rocks that make up the earth's crust, but science has categorized all the rocks into three types: igneous, metamorphic and sedimentary.
3. Define an igneous rock and show an example. Igneous rock is molten material that has *cooled and lithified* (hardened into rock). Igneous literally means 'fire' rock, so ask children words that have 'ign' in them that mean fire (*ignite, ignition*).
4. Define metamorphic rock. Metamorphic rock is rock that has been *changed* through the process of *extreme heat and pressure*. 'Morph' means change. Like the Mighty *Morphing* Power Rangers. (You are on the cusp of this analogy; the Power Rangers are falling out of favor). Caterpillars *metamorphose* into butterflies. Show an example of a metamorphic rock.
5. Define sedimentary rock. First define sediment, then explain sedimentary rocks are created from sediments that *deposited* and then *cemented* together, creating a rock. It is good to show sandstone for the example because it is easier to see the individual grains.
6. Ask students if an igneous rock today will always be an igneous rock. Ask if it can erode (break down) and become something else. Ask if it can become sedimentary rock (through weathering, erosion, deposition, cementation). Ask if it can change into a metamorphic rock (subject it to extreme heat and pressure-plate tectonics). Do this with each rock type until you have completed the entire "rock cycle." Make sure that it is clear that these processes take millions of years.
7. Read a scenario (attached) and have the students determine what rock they have become. Without talking, the students move in a large group to the correct rock type station. Emphasize that each student think for him or herself—the group may be wrong.

Other thoughts:

- Make sure students understand that this is the rock "cycle," and that any rock that is broken down through weathering or erosion, or melted, or changed by heat and pressure, may become another rock type.
- A variation that may work better. Divide students into groups. Give each group a set of scenario cards. Have the groups move to each station individually to avoid the mob scene. This idea needs some work, but it will also minimize kids who don't know the answer and are instead "just moving with the crowd".

Scenario #1

You are the hot molten magma deep beneath a volcano. Eventually you erupt to the surface. As you flow down the volcano's side, you cool and harden into this type of rock.

Answer: *Igneous* (volcanic, lava)

Follow up questions:

1. What clues told you it was an igneous rock?
2. Do you know where the closest volcano is?
3. What volcano erupted most recently within the lower 48 states? (Mt. St. Helens - 1980, before these kids were born.)

Scenario #2

You are now an igneous rock. Rain beats down on you over time, weathering you, loosening you from the volcano's side. You take a long journey tumbling down the side of the mountain. By the time you reach the bottom you are a grain of sand on a beach at the volcano's base. Millions of years go by, and more sand begins to bury you. As the sand piles on top, you, at the bottom, begin to feel the pressure from above. As water slowly filters through the sand it begins to cement you to your neighbors. You have become this type of rock.

Answer: *Sedimentary*

Follow up questions:

1. What process turned you from a rock to a grain of sand? (Weathering and erosion)
2. What places around the earth have volcanoes close to the ocean?
3. What kind of sedimentary rock do you think you have become?
4. What sediment makes sandstone?

Scenario #3

You are now a sedimentary rock. The plate you are sitting on is slowly moving. After millions of years your plate collides with another. Eventually you are forced beneath the other plate, deep into the Earth's crust. There you melt into a liquid again. After millions of years, you slowly begin to cool beneath the Earth's surface. What rock have you become?

Answer: *Igneous* (intrusive, plutonic)

Follow up questions:

1. What clues showed you became an igneous rock again?
2. How are you different from the first time you were igneous?
3. How many of you thought you had become metamorphic?
4. What does this scenario tell us about the rock cycle?

Note: If you haven't already, this may be a good time to tell the students about zones of subduction, giving some locations on the earth where they can be found.

Scenario #4

You are once again an igneous rock. Millions of years pass and your plate begins to collide with another. This time you are not forced beneath the other plate but instead you have a head on collision. As the rocks from the two plates collide, they push against each other twisting and cracking (folding and faulting). There is a tremendous heat and pressure that changes you into this type of rock.

Answer: *metamorphic*

Follow up questions:

1. What clues revealed you had become metamorphic?
2. How was this different from igneous rock?
3. Under heat and pressure, do you know what type of metamorphic rock Shale/mudstone becomes? (slate, phyllite, schist or gneiss—depending on the intensity of metamorphism)

Note: In metamorphosis, the rock's crystalline structure changes by reforming crystals and growing new ones.

Activity follow-up questions:

1. What machine drives the rock cycle? (Plate tectonics)
2. Does the rock cycle ever stop?
3. What are the 3 categories of rocks?
4. Could a rock go from a sedimentary rock to a metamorphic rock? Could a metamorphic rock become a sedimentary rock? Could a metamorphic rock become an igneous rock?
5. Could a rock go through the entire cycle in our lifetime?
6. Does geology move quickly or slowly compared to our lives?

Create a Grand Canyon Geologic Timeline

Grand Canyon Focus:	Geology
School Subject:	Science, Social Studies
Grade Level:	4 th through 8 th Grade
AZ Standards Addressed:	Science: 6SC-E4 PO1 (4-5), PO2 (4-5); Social Studies: 1SS-F1 PO2 (1-3)

Lesson Overview

Students will construct a timeline of the Earth's geologic history.

Lesson Objectives

Students will be able to describe the sequence of geologic events that occurred to form Grand Canyon. Through this exercise, students will begin to conceptualize a relationship between human historical events and geologic events.

Materials

- large cards made of a fairly stiff paper or thin cardboard
- markers, crayons, and/or colored pencils
- large piece of butcher paper at least 46 feet long
- measuring tape

Background Information

The earth is very old — about $4\frac{1}{2}$ billion years — according to recent estimates. This vast span of time, called geologic time by earth scientists, is difficult to comprehend in the familiar time units of months and years, or even centuries. How then do scientists reckon geologic time, and why do they believe the Earth is so old? The evidence for an ancient Earth is concealed in the rocks that form the Earth's crust and surface. The rocks are not all the same age—or even nearly so—but, like the pages in a long and complicated history, they record the Earth-shaping events and life of the past. The record, however, is incomplete. Many pages, especially in the early parts, are missing and many others are tattered, torn, and difficult to decipher. But enough of the pages are preserved to reward the reader with accounts of astounding episodes which certify that the Earth is billions of years old.

The oldest known rocks on Earth are close to four billion years old. They are found on the shores of Great Slave Lake in Canada's Northwest Territory and in remote areas of Greenland. The rock layers of Grand Canyon range in age from 1800 million years old at the bottom of the canyon to 270 million years old at the top. The canyon landscape we see today, however, is relatively young, having been sculpted in just the last 5-6 million years. The metamorphic rocks, found at the bottom of the canyon formed when sedimentary rocks were subjected to igneous intrusions followed by deep burial. Subsequent flooding by inland seas and windy desert conditions deposited and then reworked the sedimentary rock layers above them. The canyon seen today is relatively young, having been sculpted in just the last 5-6 million years. The Colorado River carved through many rock layers to create Grand Canyon. Lateral erosion widened the canyon.

Procedure

1. Create a timeline with rope or piece of butcher paper. Determine how long you want the rope to be. Remember we're covering 4,600 million years of geologic history. The longer the timeline, the better.

We suggest a **46 foot rope: 1 foot = 100 million years**

2. Make geologic time cards by cutting apart the following geologic events (see pages 35-40). If desired, you can cut and paste each geologic event description on 8 $\frac{1}{2}$ x 11 paper or heavy stock. This allows room for the drawing described in step 3.
3. Students can work individually or in groups. Give each group a Grand Canyon geologic time card. Have the students draw a picture on the card to represent the event listed on their card.
4. Ask the students to take five minutes to decide where they think their card should be placed on the Earth timeline. You may need to discuss scale on a timeline.
5. Each team makes a short presentation to the group explaining why and where they think their card should go and then placing it in the appropriate location on the timeline.
6. Walk through the timeline in chronological order, discussing the major geological events with respect to the depositional environment and the type of rock left behind. Explain that the rock had to be deposited before the canyon could ever exist.

Extension:

Have students do further research on their rock's depositional environment before drawing the picture.

(Ex: what is a brachiopod, cephalopod, cross-bedding, trilobite, why do some rocks form slopes and others cliffs, etc...)

The Earth Took Form

4,600 mya

The Vishnu Schist and other basement rocks formed 1,840-1,680 mya

Precambrian Era

Metamorphic rocks and intrusive igneous rocks formed deep within the earth's crust when volcanic islands created by subduction collided with the ancestral North American Plate. Life did not yet exist on the earth.

The Vishnu Schist is the dark colored metamorphic rock that forms the narrow gorge at river level in the bottom of the Grand Canyon. Other basement rocks, such as Zoroaster Granite, are intrusive igneous rocks that look like pink veins running through the darker-colored metamorphic gorge. They are the oldest exposed rocks at Grand Canyon National Park.

The Bright Angel Shale

formed 515 mya

Paleozoic Era (Cambrian Period)

The Grand Canyon area was covered by a very muddy, warm, shallow sea. Trilobites, brachiopods, crinoids and worm-like creatures that burrowed in the sea-floor thrived in the nutrient-rich water.

This greenish-colored shale forms the broad, flat area known as the Tonto Platform in the Grand Canyon.

The Redwall Limestone

formed 340 mya

Paleozoic Era (Mississippian Period)

North America lay close to the equator. The Grand Canyon area was covered by a shallow, warm, and clear well-lit sea where crinoids lived in abundance. Other species included corals, bryozoans, brachiopods, and cephalopods.

This limestone layer creates a 500 foot cliff in most areas of the Grand Canyon. The surface of the exposed cliffs are stained red by iron that seeps down from the layers above with rain and snow melt, but the limestone itself is gray in color.

The Supai Group

formed 315-285 mya

Paleozoic Era (Pennsylvanian and early Permian Periods)

The Grand Canyon area was covered by rapidly changing coastlines as sea levels rose and fell. Therefore, the Grand Canyon area was sometimes covered with beaches and dunes, and sometimes covered with sea water. The marine environments contained a rich population of brachiopods, while the terrestrial environments hosted sparse distributions of plants. Both types of environments had multiple types of burrowing creatures.

This layer consists of a wide variety of rock types, including limestones, mudstones, and sandstones that form a series of cliffs and slopes, which look like stairs into the Grand Canyon.

The Hermit Formation

formed 280 mya

Paleozoic Era (Permian Period)

The Grand Canyon area was covered by a broad coastal plain fed by multiple slowly meandering streams. The environment was prime habitat for an abundance of ferns and conifers, along with reptiles and insects, including dragonflies with three-foot wingspans.

This layer consists of siltstones, mudstones, and fine grained sandstones rich in iron that create a gentle slope in most parts of Grand Canyon National Park.

The Coconino Sandstone

formed 275 mya

Paleozoic Era (Permian Period)

North America lay near the equator. The Grand Canyon area was covered with coastal dune-fields that reached as far north as present day Monument Valley, and as far south as Sedona. The ocean lay to the west. Reptiles, spiders, scorpions, and other insects dwelled on the sand dunes of this extensive desert.

This sandstone layer creates a broad, light-colored cliff a few hundred feet below the rim of Grand Canyon. Cross-bedding (lines that run at steep angles to one-another) can be seen in the rock, giving evidence to the sand dunes that once covered the area.

The Kaibab Formation

formed 270 mya

Paleozoic Era (Permian Period)

North America was the western part of the super-continent Pangaea. The Grand Canyon region was once again covered by a shallow, warm, and well-lit clear sea with a sandy/muddy floor. The coast was nearby and to the northeast. Brachiopods and sponges dominated these waters. Other species included crinoids, corals, bryozoans, cephalopods, sharks and fish.

This limestone is the top-most layer, and thus the youngest rock, found at Grand Canyon National Park.

Dinosaurs First Appear

230 mya

Mesozoic Era (Triassic, Jurassic, and Cretaceous periods)

The Paleozoic Era ended about 250 mya with the largest mass extinction known; 90% of all known living organisms died. Thus began the Mesozoic Era, known as the Age of the Reptiles. Reptiles during the Mesozoic dominated the land, skies and seas.

Most well-known are the dinosaurs, which first appear 230 mya and evolved into the largest land animals ever known. They walked with their legs tucked under their bodies, unlike living reptiles, which have splayed legs.

Dinosaurs Went Extinct

65 mya

End of Cretaceous Period (End of Mesozoic Era)

Approximately 50% of all known living species, including the dinosaurs, died out at the end of the Cretaceous Period (this also marks the end of the Mesozoic Era). This extinction coincides with the impact of a large meteorite in the Caribbean Sea off the Yucatan Peninsula in Mexico. The resulting shock waves, tidal waves, and intense heat, followed by years of cold and darkness, are all thought to have contributed to the disappearance of so many life forms.

Colorado Plateau Uplift

Began 60 mya

The Colorado Plateau was lifted up high above sea-level during the Laramide Orogeny, a mountain-building event that culminated in the uplift of the Rocky Mountains.

The Colorado River began to carve Grand Canyon

5-6 mya

There is much debate as to how the Colorado River started to carve the Grand Canyon, however geologic evidence indicates that the canyon is no more than 5 or 6 million years old. The Colorado River is 1,400 miles long and empties into the Gulf of California, which itself is no older than 5.5 million years old.

Present Day

Dynamic geologic processes are at work today. Even Grand Canyon is not static and continues to slowly become wider and deeper as the processes of weathering and erosion endlessly grind away at the rock.

Canyon Carver

Grand Canyon Focus: Geology
School Subject: Science
Grade Level: 1st through 6th Grade
AZ Standards Addressed: Science: 6SC-F5 (1-3) PO1, PO2; 6SC-E6 PO1 (6-8), PO2 (6-8)

Lesson Overview

Students will demonstrate the process of erosion (transportation of sediment by water) using the milk carton technique.

Lesson Objective

Students will learn the basics of erosional processes and how they form the landscape of Grand Canyon.

Materials (each group of two or more students will need)

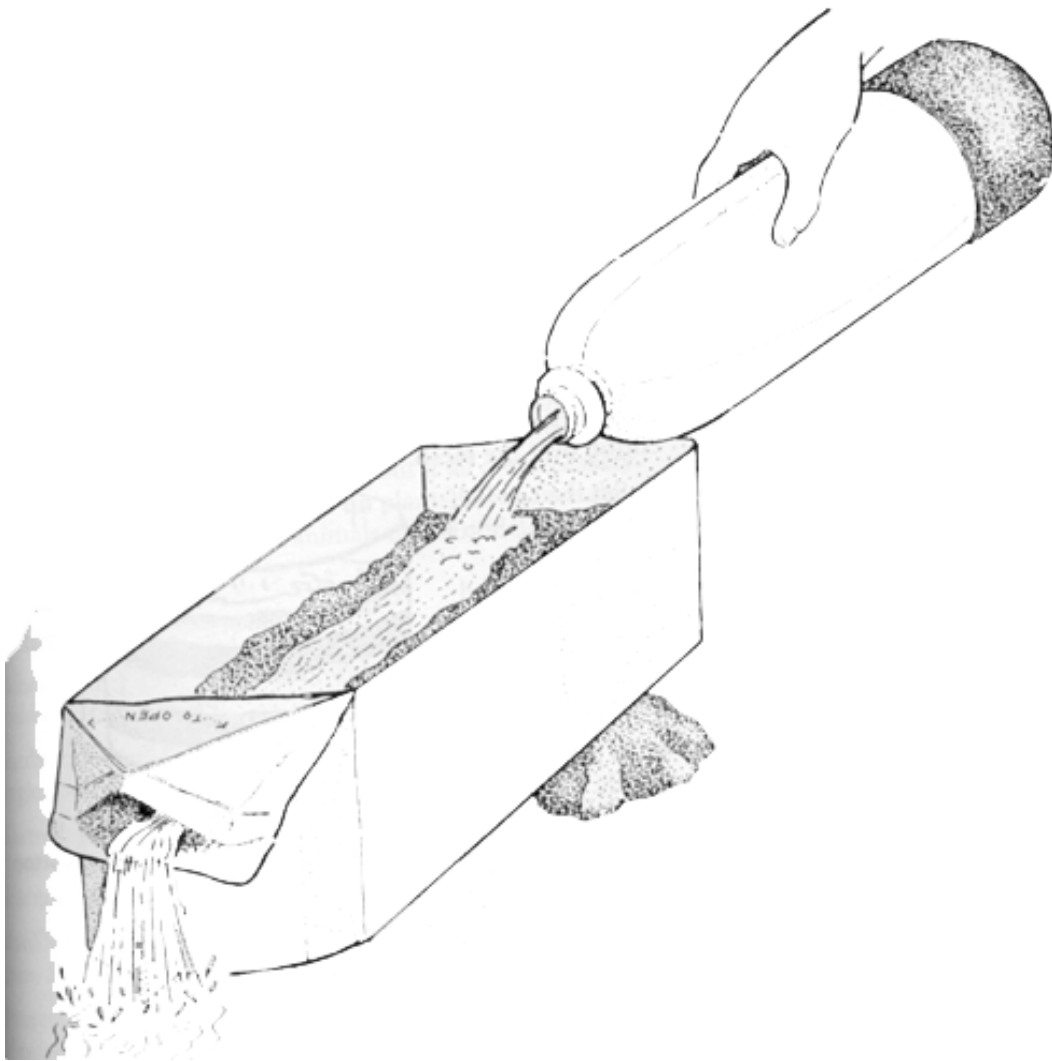
- 1.9-L milk carton
- 2.0-L (water) bottle
- source of sediment (sand or potting soil)
- ruler
- scissors
- source of water
- garden trowel

Background

Students often know that rivers such as the Colorado River can be muddy. But they may not know that some of the sediment (sand, silt, and clay) that makes the river muddy comes from the riverbed itself and is a result of the river cutting down. The canyon, and all of the formations within it, result directly from weathering and erosion in various forms. The Grand Canyon is one of the world's greatest examples of arid land erosion through layers of stratified rock.

Procedure

1. Provide each team with an empty half-gallon milk carton.
2. Use scissors to cut out the side panel of the carton under the spout, leaving the spout intact. For younger students, you may prefer to do this cutting ahead of time.
3. (You may wish to continue this activity outside; don't forget all the necessary materials.) Lay the carton on its side with the cut out panel facing up. Fill the container about half full with the sediment, of which you may wish to smooth the surface.
4. To simulate a flowing river, set one end of the carton approximately 1-cm higher than the other end, using something to prop it up such as a rock or piece of bark. Be sure the lower end of the carton is the one with the spout.
5. Place the mouth of the (water) bottle on the higher end and slowly pour the water out. The water should flow steadily down and out the spout end. Remember, the water flow will be directly affected by your sediment choice and degree of its saturation.
6. Continue repeating steps 3-5, but raise the elevated end a cm or two at a time. Then discuss the various depths and formations created.



Make a Fossil

Grand Canyon Focus: Paleontology
School Subject: Science
Grade Level: 3rd through 8th Grade
AZ Standards Addressed: Science: 6SC-F8 (1-3); 6SC-E4 PO1 (4-5), PO2 (4-5), PO1 (6-8)

Lesson Overview

Students will simulate making a fossil.

Lesson Objectives

Students will learn what fossils are and how they are formed. Students will also understand how fossils and the rock layers they are found in can be used as clues to the past.

Materials

- clear plastic cups, petroleum jelly, and tubs of various colored mud
- something to scoop mud with (scoops, trowels, large spoons, etc.)
- shells, leaves, plastic animals and/or their tracks, plastic plants, bones (cleaned chicken bones work well)
- small digging tools such as toothpicks, spoons, etc.
- paper, pencil or pen, and art supplies such as crayons, colored pencils, etc.
- optional: Plaster of Paris, disposable cups (7 oz.), plates and spoons, modeling clay, and water

Background

A fossil is any evidence of ancient life. This evidence may be the actual remains, such as bone, teeth, shells or plant tissues; chemically altered remains; or traces of the activities of organisms, such as burrows and tracks. Paleontology is the study of fossils. Scientists who study fossils are paleontologists. Paleontologists use fossils to reconstruct ancient life, using what we know about the present to understand the past and drawing upon the sciences of geology and biology. Paleontology is often confused with archaeology, which is the study of ancient humans and their cultures. The focus of paleontology is the history of life on earth, from its beginnings approximately 3.6 billion years ago, up to the advent of human culture about 10,000 years ago. Except for rare occurrences, fossils are found only in sedimentary rocks.

Upon death, most plant and animal remains are soon digested by bacteria and other living organisms. Thus some of the organic elements of life are recycled to build new organisms. Rare and special circumstances are necessary for any parts or traces of an organism to be preserved as a fossil. Preservation usually requires that an organism or its remains be buried rapidly, be insulated from oxygen and decay-producing organisms, and remain buried and undisturbed. Under even the best of conditions, the preservation of soft parts is exceptionally rare. Usually only hard skeletal elements are preserved as fossils.

Fossils are not always the actual remains of living organisms. Many fossils are just copies called imprints, molds, or casts. Imprints are impressions made by organisms in soft sediment that were preserved when the sediment solidified. Imprints can be traces of an animal's activity, rather than its actual remains. The hardened tracks of animals or the burrows of prehistoric worms in solidified mud are examples of fossil imprints. Molds are made when organisms are totally or partially buried in sediment that hardens into rock. Over time, ground water may dissolve the organisms, leaving cavities shaped like their bodies. Both imprints and molds are mirror images of the organisms. If a mold was later filled with mud or mineral material, the hardened filling is called a cast. It is a reproduction that

has the same outer shape as the organism. A cast looks like the organism itself, not like its imprint. Paleontologists make casts of fossil molds by filling them with liquids, such as plaster, that harden.

Procedure

1. Ask the class what they think a fossil is and how they think fossils are formed. Tell them that they are now going to simulate the making of a fossil.
2. Distribute a clear plastic cup to each student, or to each group if they will be working cooperatively. Grease the inside of the cup with a thin layer of petroleum jelly. Have several tubs of mud available, preferably of different shades or colors. Explain that they are going to simulate a body of water (lake, ocean, etc.) in which sediment (mud, sand, etc.) is slowly being deposited. In this water body, plants and animals fall to the bottom when they die. Add liquid mud to the cup in increments, alternating colors and allowing the mud to settle between each addition. Have the students add small shells, leaves, plastic animals/plants, or bones on top of some of the layers of mud. Choose only one type of item for each layer. Ask the students which layer is the "oldest" (that is, which layer is laid down first) and which is the "youngest" (that is, which layer is laid down last). Tell them that this is known in geology as the law of superposition which states that, in any sequence of sedimentary strata (layers) that has not been overturned, the youngest stratum is at the top and the oldest is at the base.
3. Dry the sediment. The drying of the mud simulates turning the sediment into rock. Drying will take place much faster if the cups are placed in a warm, dry place for a few hours. Remind the students that real fossilization is a bit more complicated and does not happen this quickly but can take millions of years.
4. Have the students swap cups. If possible, carefully remove the hardened mud from the cup. Students can then excavate the "fossils" using simple tools such as toothpicks, spoons, etc.
5. Have each student write a story and draw a picture (or make a diorama) about each "environment" based on the "fossils" they find in each layer. For example, if they found a shell, they might draw a picture of an ocean, and write a description of what that ocean might have been like. Remind them to start with the oldest layer and work forwards in time, pretending that the layers were formed over millions of years. Discuss how our knowledge of today's environments might help them decide what the past environments were like. Some things to consider are:
What other animals and plants might have been living in that environment? What did those plants and animals need to survive? What did they eat and who ate them? What dangers might have threatened them? What was the climate like? What did the landscape look like?

Extension (making fossil casts)

1. Squeeze clay until it is pliable and place the clay on a paper plate.
2. Coat one side of a shell, thick green leaf, plastic animal footprint, flat plastic plant (such as a fake fern), or bone with petroleum jelly. Press the lubricated side of the item into the clay. Carefully remove the item from the clay. Observe the imprint. Compare the imprint in the clay with the shape and texture of the item.
3. Place four spoonfuls of dry plaster of Paris and two spoonfuls of water in disposable cup and stir with a disposable spoon until smooth. Pour the plaster mixture into the shell imprint in the clay. Allow the plaster to harden. This will take about 20 minutes. (Note: Do not wash any plaster down the sink as it can clog the drain. Throw the cup and spoon away.)
4. Gently separate the clay from the plaster. Compare the shape and texture of the item with the shape and texture of the plaster cast.

Fossilization Game

Grand Canyon Focus: Paleontology
School Subject: Science
Grade Level: 3rd through 6th Grade
AZ Standards Addressed: Science: 6SC-F8 (1-3); 6SC-E4 PO1 (4-5), PO2 (4-5), PO1 (6-8)

Lesson Overview

Students will play a game to understand the fossilization process.

Lesson Objective

Students will understand the fossilization process and why some things get fossilized and some things don't.

Materials

- Fossilization cards

Background

See previous activity titled *Make a Fossil*.

Procedure

1. Have students choose an environment in which there is a depositional setting such as a lake, pond, stream, swamp, desert, river, forest, or sea floor. The students can use their imaginations to describe this setting in as much detail as they desire.
2. Each student should then choose the role of an animal or plant that might inhabit the environment they have chosen (alternative suggestion: you can also put roles on cards and hand them out to the students). For example, in an aquatic setting, possible roles include not only snails, clams, fish, salamanders, turtles, alligators, and other aquatic animals, but also horses, deer, monkeys, rabbits, and birds that come to drink. Help students think of ways they could act out their animal or plant and how different roles might interact. For instance, a fish might wiggle and make gulping noises, a plant might grow or sway in the breeze or current, carnivores might chase predators, herbivores might nibble on plants, etc.
3. Have the students act out their roles. Each can be given a turn to make vocalizations or gestures. Students can also interact with each other as they might in their natural environment.
4. At a time determined by the teacher, the teacher yells "freeze" (or makes a noise with some kind of sound maker such as a whistle or duck call). "Freeze" means that the time for possible fossilization begins and all students must stop in their tracks. The teacher then has each student pick a card which will tell their fate. Use the cards below, or make up your own. If you need more cards, simply make a double set. Be sure that there are many more "destruction" cards than "fossilization" cards to represent the small chance of something being fossilized in the real world. Students can then act out the role of their demise or fossilization.
5. Discuss the meaning of this exercise. Have each student discuss his or her role as an organism and what happened to this organism after it died. On the blackboard, make one list of the organisms that were fossilized and another list of those that were destroyed. Remind the students that the only animals and plants future paleontologist will know anything about are the ones that become fossils. Discuss whether your list of fossils is a good representation of the living community they just acted out. Ask the students how this might affect the science of paleontology.

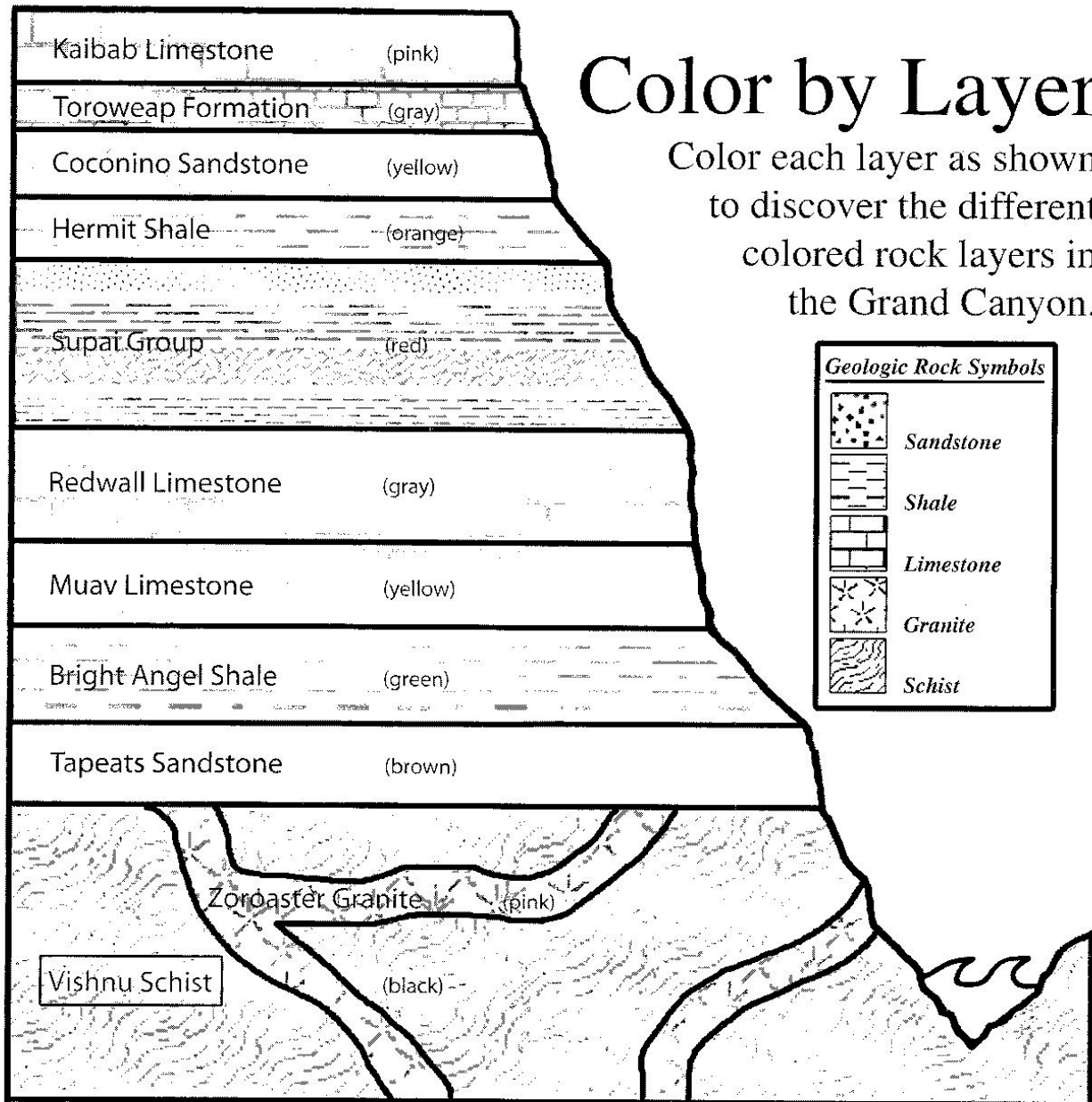
Extension

Play the game again with a new environment, this time asking a few of the students to pretend to be paleontologist and leave the room before the new environment is decided. After the rest of the students have acted out their parts and then received their fate cards, have the destroyed plants and animals leave the scene. The "paleontologists" can then enter the room and examine the "fossils" (allow them to read the cards and ask what plant or animal the fossil was). The paleontologists should work as a team, taking notes of their findings and then trying to determine what the environment was. They can also make educated guesses as to what plants and animals are missing from the fossil record. The rest of the class can tell them the answers after the paleontologists are done with their study.

Dry up	Dry up
Rot away	Rot away
Rot away	Eaten alive by an animal
Eaten alive by an animal	Eaten alive by an animal
Eaten alive by an animal	Eaten alive by an animal
Eaten by scavengers after death	Eaten by scavengers after death
Buried in sediment (mud, dirt, sand, etc.) - your harder body parts become a fossil!	Buried in sediment (mud, dirt, sand, etc.) - your harder body parts become a fossil!
Washed away by water	Washed away by water
Washed away by water	Washed away by water

You rot away but your imprint or track is buried in sediment (mud, sand, dirt, etc.) and becomes a fossil!	Rot away
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Grand Canyon



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